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Eric Hoffmayer, Jill Hendon, and Adam Pollack

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STANDARDIZED CATCH RATES OF BLACKTIP SHARKS (*CARCHARHINUS LIMBATUS*) COLLECTED DURING A BOTTOM LONGLINE SURVEY IN MISSISSIPPI COASTAL WATERS, 2004-2011.

Eric R. Hoffmayer[1], Jill M. Hendon[2], and Adam G. Pollack[1]

Beginning in 2004, an ongoing monthly standardized bottom longline survey has been conducted in Mississippi coastal waters from March to October each year. This fisheries independent dataset was developed to monitor the abundance and distribution of various elasmobranch and teleost species within Mississippi's coastal waters. As a result of 333 sets and 431 hours of effort, 196 blacktip sharks were collected. Because the work was conducted in a known blacktip nursery area, blacktip shark catch was further divided into young-of-the-young (YOY, age-0), juvenile and adult catch. Due to the low occurrences of YOY and adult sharks in the dataset, an abundance index was not produced for either of these groups. Standardized catch rates were estimated using a Generalized Linear Mixed modeling approach assuming a delta-lognormal error distribution and negative binomial regression. Other than a slight peak observed in the standardized index for 2005, total blacktip catch rates remained stable across the time series. The juvenile blacktip index mimicked the total blacktip index.

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[1]NOAA, National Marine Fisheries Service, Southeast Fisheries Science Center, Mississippi Laboratories, Pascagoula, Mississippi 39567; [2]Center for Fisheries Research and Development, The University of Southern Mississippi. Gulf Coast Research Laboratory. 703 East Beach Drive. Ocean Springs, MS 39564.

INTRODUCTION

The University of Southern Mississippi's Gulf Coast Research Laboratory (GCRL) developed a standardized bottom longline survey within the waters of the Mississippi Sound, which has been conducted monthly from March to October, since 2004. The Mississippi bottom longline survey is funded by the Mississippi Department of Marine Resources through the U.S. Fish and Wildlife Service (Sports Fish Restoration Act). The primary objective of this survey is to collect data on the seasonal abundance and distribution of local shark and teleost species in Mississippi coastal waters. The funding for this survey has continued through 2012 and will most likely continue in the foreseeable future.

METHODOLOGY

Sampling Locations

From 2004 to 2011 sharks were collected at various sites along the Mississippi coast extending east to west from Petit Bois Island to St. Louis Bay. In general, collections were made from March to October with five to seven locations sampled each month. Sampling was confined to the waters of the Mississippi Sound, which was broken into twelve 10.6 km^2 sampling regions, from which monthly sampling locations were randomly selected. The sampling regions included east and west Cat, east and west Ship, Deer, east and west Horn, Round, Sand, and east and west Petit Bois Islands (Figure 1).

Sampling Protocol

Sampling was conducted with a 152.4 m bottom longline that consisted of 50 hooks (12/0 circle), 1.0 m gangions (2.0 mm), and menhaden (*Brevoortia patronus*) as bait. The longline was typically fished between the hours of 0800 and 2000, and was allowed to soak for 1 hour prior to retrieval. The soak time was defined by the time between the setting of the first hook and the retrieval of the last hook. As expeditiously as possible, each shark captured was identified and measured (fork length, FL) and its sex and, when possible, maturity state recorded. Water temperature (°C), salinity (psu), and dissolved oxygen (mg/l) were measured at the water's surface and near the bottom at each sampling location. Water depth (m) and latitude and longitude were also recorded at each station.

Analysis

For the purpose of analysis, blacktip sharks were divided into size classes based on estimates of their growth rates and size at maturity. Blacktip sharks were designated young-of-year (YOY) when between 380 and 659 mm fork length (FL), juvenile when between 660 and 1034 mm FL (male) and between 660 and 1173 mm FL (female), and adult when >1035 mm FL (male) and >1174 mm FL (female) (Carlson et al. 2006). Detailed analyses of YOY and adult catch rates were not performed because of their small number of positive catches in the dataset (4.2 and 5.7%, respectively). Catch rates were standardized as catch per unit effort (CPUE) in sharks per 100 hook * hour for juvenile blacktip sharks as well as for all blacktip sharks. Length frequency distributions were constructed for blacktip sharks ranging from 380 to 1210+ mm FL using 100 mm increments.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for blacktip sharks (Lo *et al*. 1992). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data (Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) as described by Lo *et al*. (1992) was estimated as:

(1) $$I_y = c_y p_y,$$

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(2) $$\ln(c) = X\beta + \varepsilon$$

and

(3) $$p = \frac{e^{X\beta+\varepsilon}}{1+e^{X\beta+\varepsilon}},$$

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE(c_y) and SE(p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated as:

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(5) $$\mathrm{Cov}(c, p) \approx \rho_{c,p}\left[\mathrm{SE}(c_y)\mathrm{SE}(p_y)\right],$$

and $\rho_{c,p}$ denotes correlation of c and p among years.

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.10$. Binomial submodel

performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC.

For all indices developed, the factors YEAR, MONTH, LOCATION, DEPTH, SET, MONTHLY RAINFALL (MONTHLY R), PREVIOUS MONTH RAINFALL (PREV MON R), SURFACE (SUR) and BOTTOM (BOT) TEMPERATURE (TEMP), SALANITY (SAL), and DISSOLVED OXYGEN (DO) were examined for inclusion in the catch rate models. The factor MONTH includes the months that sampling was conducted from March to October. The Mississippi Sound was divided into two zones: east to west (1 and 2) which is represented by factor LOCATION. The factor SET refers to the time of day the bottom longline was first deployed at the sampling location. The factors MONTHLY R and PREV MON R included the mean monthly rainfall (inches) in Mississippi's three coastal counties. The factors DEPTH, TEMP, SAL, and DO included values present in the data set. The factor YEAR included each year in the time series from 2004 to 2011, and was included in the model whether it explained the data or not, so that an annual catch rate series was produced.

RESULTS

From 2004 to 2011, 333 locations in Mississippi coastal waters were sampled resulting in 431 hours of effort. During this time 196 blacktip sharks were collected (Figure 2). The total number of blacktip sharks captured each year ranged from 4 to 52 sharks (Table 1). The blacktip shark catch consisted primarily of juveniles (n = 149) with relatively few YOY (n = 23) and adults (n = 24) present. Approximately 27% of the stations contained positive catches of blacktip sharks, with YOY, juvenile, and adult sharks occurring at 4.2, 21.3, and 5.7% of the stations, respectively. Due to the low occurrence of YOY and adults in the dataset, no further analysis was performed on either of these groups.

In the Mississippi bottom longline survey, blacktip sharks ranged in size from 380 to 1,650 mm FL (mean: 793.5 ± 14.5 mm FL). The length frequency histogram (Figure 3) indicated that 81.6% of the sharks were between 600 and 1100 mm FL. The nominal CPUE and number of stations with a positive catch for total and juvenile blacktip are presented in Figures 4-5, which indicated annual variation in nominal CPUE, with varying proportion of positive catches over the years.

Total Blacktip Catch

For the total blacktip model, YEAR, MONTH, DEPTH, TEMPSUR, SALSUR, MONTHLY R and PREV MON R were retained in the binomial submodel. The variables retained in the lognormal submodel were YEAR, DEPTH, and SALBOT. Table 2 summarizes the backward selection procedure used to select the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 1763.4 and 179.9, respectively. The AIC for the lognormal submodel increased slightly from model run #10 to #11 when factor MONTH was removed ($p = 0.2197$); however, we felt this still produced the best final model results. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 6-8, and indicated the distribution of the residuals is approximately normal. Annual

abundance indices are presented in Figure 9 and Table 3. Nominal and standardized blacktip catch rates remained relatively stable throughout the survey with a slight peak in abundance occurring in standardized index in 2005 (Figure 9).

Juvenile Blacktip Catch

For the juvenile blacktip model, YEAR, MONTH, TEMPSUR, SALBOT, PREV MON R, and MONTHLY R were retained in the binomial submodel. The variables retained in the lognormal submodel were YEAR, MONTH, and DOBOT. Table 4 summarizes the backward selection procedure used to select the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 1841.9 and 134.4, respectively. The AIC for the binomial submodel increased slightly from model run #4 to #6, but steadily declined for each subsequent run when non-significant variables were removed. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 10-12, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Figure 13 and Table 5. Both the nominal and standardized juvenile blacktip shark catch rates remained relatively stable throughout the time series; however, a slight decline in catch rates was evident in 2008, 2009, and 2011 (Figure 13).

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Table 1. Summary of the blacktip shark data used in these analyses collected during the Mississippi bottom longline survey conducted between 2004 and 2011.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
2004	44	35	35	424	1278	742	160
2005	29	25	25	455	1130	790	180
2006	35	24	24	544	1105	835	150
2007	44	51	51	410	1650	872	250
2008	33	14	14	385	865	562	140
2009	32	4	4	600	738	671	760
2010	59	37	37	380	1160	795	150
2011	57	6	6	490	1440	870	320

Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured	Overall Mean Fork Length (mm)
8	333	196	196	793

Table 2. Summary of the backward selection procedure for building delta-lognormal submodels for the total blacktip shark full index of relative abundance from 2004 to 2011.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 1808.2)*						*Lognormal Submodel Type 3 Tests (AIC 206.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	150	20.34	2.85	0.0049	0.0082	7	65	1.22	0.3042
Month	7	234	15.17	2.16	0.0339	0.0386	7	65	1.11	0.3693
location	1	288	0.25	0.25	0.6184	0.6187	1	65	0.31	0.5786
Depth	1	270	2.22	2.22	0.1367	0.1378	1	65	8.36	0.0052
Set	1	284	1.44	1.44	0.2303	0.2313	1	65	1.10	0.2980
Tempsur	1	264	2.92	2.92	0.0874	0.0886	1	65	0.22	0.6434
Tempbot	1	210	0.14	0.14	0.7099	0.7103	1	65	0.02	0.8929
Salsur	1	253	1.63	1.63	0.2022	0.2033	1	65	0.01	0.9080
Salbot	1	243	0.42	0.42	0.5192	0.5198	1	65	2.01	0.1614
DOsur	1	160	0.07	0.07	0.7857	0.7860	1	65	0.00	0.9831
DObot	1	169	0.62	0.62	0.4324	0.4335	1	65	1.03	0.3151
Prev_Mon_R	1	216	11.09	11.09	0.0009	0.0010	1	65	0.61	0.4391
Monthly_R	1	199	2.49	2.49	0.1144	0.1160	1	65	0.51	0.4786

Model Run #2	*Binomial Submodel Type 3 Tests (AIC 1801.6)*						*Lognormal Submodel Type 3 Tests (AIC 204.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	149	20.99	2.94	0.0038	0.0066	7	66	1.24	0.2940
Month	7	235	15.70	2.23	0.0280	0.0323	7	66	1.21	0.3079
location	1	292	0.27	0.27	0.6024	0.6028	1	66	0.32	0.5754
Depth	1	261	2.16	2.16	0.1416	0.1428	1	66	9.14	0.0036
Set	1	281	1.31	1.31	0.2523	0.2533	1	66	1.30	0.2579
Tempsur	1	268	2.84	2.84	0.0917	0.0929	1	66	0.23	0.6345
Tempbot	1	219	0.19	0.19	0.6620	0.6624	1	66	0.02	0.8918
Salsur	1	268	1.64	1.64	0.2010	0.2021	1	66	0.01	0.9044
Salbot	1	246	0.48	0.48	0.4891	0.4898	1	66	2.19	0.1440
DOsur					Dropped				Dropped	
DObot	1	162	0.54	0.54	0.4624	0.4635	1	66	1.04	0.3104
Prev_Mon_R	1	216	11.05	11.05	0.0009	0.0010	1	66	0.62	0.4326
Monthly_R	1	199	2.60	2.60	0.1069	0.1085	1	66	0.59	0.4443

Model Run #3	*Binomial Submodel Type 3 Tests (AIC 1797.1)*						*Lognormal Submodel Type 3 Tests (AIC 199.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	149	22.93	3.21	0.0018	0.0034	7	67	1.26	0.2853
Month	7	236	15.76	2.24	0.0274	0.0316	7	67	1.25	0.2902
location	1	299	0.34	0.34	0.5614	0.5619	1	67	0.31	0.5814
Depth	1	267	2.26	2.26	0.1325	0.1336	1	67	9.30	0.0033
Set	1	280	0.85	0.85	0.3563	0.3571	1	67	1.35	0.2501
Tempsur	1	282	7.84	7.84	0.0051	0.0054	1	67	0.22	0.6413
Tempbot					Dropped		1	67	0.03	0.8690
Salsur	1	279	1.91	1.91	0.1674	0.1685			Dropped	
Salbot	1	253	0.43	0.43	0.5118	0.5124	1	67	3.51	0.0652
DOsur					Dropped				Dropped	
DObot	1	163	0.70	0.70	0.4012	0.4025	1	67	1.06	0.3075
Prev_Mon_R	1	216	11.15	11.15	0.0008	0.0010	1	67	0.62	0.4346
Monthly_R	1	201	2.54	2.54	0.1107	0.1122	1	67	0.59	0.4465

Model Run #4	*Binomial Submodel Type 3 Tests (AIC 1791.8)*						*Lognormal Submodel Type 3 Tests (AIC 194.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	149	22.89	3.20	0.0018	0.0035	7	68	1.28	0.2735
Month	7	236	18.80	2.68	0.0088	0.0110	7	68	1.31	0.2568
location					Dropped		1	68	0.30	0.5876
Depth	1	250	1.94	1.94	0.1637	0.1649	1	68	9.44	0.0031
Set	1	279	0.69	0.69	0.4066	0.4073	1	68	1.38	0.2435
Tempsur	1	282	8.75	8.75	0.0031	0.0034	1	68	0.45	0.5027
Tempbot					Dropped				Dropped	
Salsur	1	275	2.05	2.05	0.1521	0.1532	1	68	3.64	0.0606
Salbot	1	260	0.66	0.66	0.4155	0.4163			Dropped	
DOsur					Dropped				Dropped	
DObot	1	177	0.84	0.84	0.3580	0.3592	1	68	1.05	0.3098
Prev_Mon_R	1	216	11.43	11.43	0.0007	0.0009	1	68	0.61	0.4393
Monthly_R	1	204	2.52	2.52	0.1121	0.1136	1	68	0.60	0.4403

Model Run #5	*Binomial Submodel Type 3 Tests (AIC 1794.7)*						*Lognormal Submodel Type 3 Tests (AIC 193.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	150	22.38	3.13	0.0022	0.0041	7	69	1.26	0.2839
Month	7	235	18.79	2.68	0.0089	0.0111	7	69	1.48	0.1890
location					Dropped				Dropped	
Depth	1	277	2.89	2.89	0.0894	0.0905	1	69	9.37	0.0031
Set	1	282	1.13	1.13	0.2869	0.2878	1	69	1.31	0.2559
Tempsur	1	282	8.65	8.65	0.0033	0.0035	1	69	0.46	0.5017
Tempbot					Dropped				Dropped	
Salsur	1	252	8.68	8.68	0.0032	0.0035			Dropped	
Salbot					Dropped		1	69	3.40	0.0694
DOsur					Dropped				Dropped	
DObot	1	166	0.64	0.64	0.4247	0.4258	1	69	1.28	0.2610
Prev_Mon_R	1	217	11.74	11.74	0.0006	0.0007	1	69	0.51	0.4784
Monthly_R	1	203	2.29	2.29	0.1302	0.1317	1	69	0.62	0.4335

Model Run #6	*Binomial Submodel Type 3 Tests (AIC 1787.1)*						*Lognormal Submodel Type 3 Tests (AIC 189.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	150	22.53	3.15	0.0021	0.0039	7	70	1.53	0.1724
Month	7	235	19.42	2.76	0.0070	0.0089	7	70	1.47	0.1909
location					Dropped				Dropped	
Depth	1	278	2.50	2.50	0.1135	0.1147	1	70	9.11	0.0036
Set	1	279	1.63	1.63	0.2015	0.2025	1	70	2.07	0.1549
Tempsur	1	284	8.34	8.34	0.0039	0.0042			Dropped	
Tempbot					Dropped				Dropped	
Salsur	1	243	8.23	8.23	0.0041	0.0045			Dropped	
Salbot					Dropped		1	70	3.12	0.0817
DOsur					Dropped				Dropped	
DObot					Dropped		1	70	1.55	0.2177
Prev_Mon_R	1	214	11.27	11.27	0.0008	0.0009	1	70	0.38	0.5400
Monthly_R	1	199	2.50	2.50	0.1141	0.1157	1	70	0.49	0.4860

Model Run #7	*Binomial Submodel Type 3 Tests (AIC 1763.4)*						*Lognormal Submodel Type 3 Tests (AIC 185.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	144	26.64	3.72	0.0004	0.0010	7	71	1.53	0.1711
Month	7	239	21.70	3.09	0.0029	0.0039	7	71	1.48	0.1885
location					Dropped				Dropped	
Depth	1	287	2.98	2.98	0.0845	0.0856	1	71	9.22	0.0033
Set					Dropped		1	71	1.99	0.1631
Tempsur	1	288	9.50	9.50	0.0021	0.0023			Dropped	
Tempbot					Dropped				Dropped	
Salsur	1	261	7.71	7.71	0.0055	0.0059			Dropped	
Salbot					Dropped		1	71	2.78	0.1001
DOsur					Dropped				Dropped	
DObot					Dropped		1	71	2.30	0.1337
Prev_Mon_R	1	200	11.14	11.14	0.0008	0.0010			Dropped	
Monthly_R	1	193	2.84	2.84	0.0922	0.0938	1	71	1.01	0.3185

Model Run #8	*Binomial Submodel Type 3 Tests (AIC 1763.4)*						*Lognormal Submodel Type 3 Tests (AIC 180.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	144	26.64	3.72	0.0004	0.0010	7	72	1.74	0.1139
Month	7	239	21.70	3.09	0.0029	0.0039	7	72	1.61	0.1471
location					Dropped				Dropped	
Depth	1	287	2.98	2.98	0.0845	0.0856	1	72	8.92	0.0039
Set					Dropped		1	72	2.19	0.1429
Tempsur	1	288	9.50	9.50	0.0021	0.0023			Dropped	
Tempbot					Dropped				Dropped	
Salsur	1	261	7.71	7.71	0.0055	0.0059			Dropped	
Salbot					Dropped		1	72	2.24	0.1385
DOsur					Dropped				Dropped	
DObot					Dropped		1	72	3.13	0.0813
Prev_Mon_R	1	200	11.14	11.14	0.0008	0.0010			Dropped	
Monthly_R	1	193	2.84	2.84	0.0922	0.0938			Dropped	

Model Run #9	*Binomial Submodel Type 3 Tests (AIC 1763.4)*						*Lognormal Submodel Type 3 Tests (AIC 177.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	144	26.64	3.72	0.0004	0.0010	7	73	1.63	0.1397
Month	7	239	21.70	3.09	0.0029	0.0039	7	73	1.74	0.1119
location					Dropped				Dropped	
Depth	1	287	2.98	2.98	0.0845	0.0856	1	73	9.53	0.0029
Set					Dropped				Dropped	
Tempsur	1	288	9.50	9.50	0.0021	0.0023			Dropped	
Tempbot					Dropped				Dropped	
Salsur	1	261	7.71	7.71	0.0055	0.0059			Dropped	
Salbot					Dropped		1	73	2.91	0.0922
DOsur					Dropped				Dropped	
DObot					Dropped		1	73	2.44	0.1226
Prev_Mon_R	1	200	11.14	11.14	0.0008	0.0010			Dropped	
Monthly_R	1	193	2.84	2.84	0.0922	0.0938			Dropped	

Model Run #10	Binomial Submodel Type 3 Tests (AIC 1763.4)						Lognormal Submodel Type 3 Tests (AIC 176.0)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	144	26.64	3.72	0.0004	0.0010	7	74	1.79	0.1020
Month	7	239	21.70	3.09	0.0029	0.0039	7	74	1.40	0.2197
location					Dropped				Dropped	
Depth	1	287	2.98	2.98	0.0845	0.0856	1	74	7.64	0.0072
Set					Dropped				Dropped	
Tempsur	1	288	9.50	9.50	0.0021	0.0023			Dropped	
Tempbot					Dropped				Dropped	
Salsur	1	261	7.71	7.71	0.0055	0.0059			Dropped	
Salbot					Dropped		1	74	4.32	0.0412
DOsur					Dropped				Dropped	
DObot					Dropped				Dropped	
Prev_Mon_R	1	200	11.14	11.14	0.0008	0.0010			Dropped	
Monthly_R	1	193	2.84	2.84	0.0922	0.0938			Dropped	

Model Run #11	Binomial Submodel Type 3 Tests (AIC 1763.4)						Lognormal Submodel Type 3 Tests (AIC 179.9)			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	144	26.64	3.72	0.0004	0.0010	7	81	1.68	0.1246
Month	7	239	21.70	3.09	0.0029	0.0039			Dropped	
location					Dropped				Dropped	
Depth	1	287	2.98	2.98	0.0845	0.0856	1	81	8.33	0.0050
Set					Dropped				Dropped	
Tempsur	1	288	9.50	9.50	0.0021	0.0023			Dropped	
Tempbot					Dropped				Dropped	
Salsur	1	261	7.71	7.71	0.0055	0.0059			Dropped	
Salbot					Dropped		1	81	6.57	0.0122
DOsur					Dropped				Dropped	
DObot					Dropped				Dropped	
Prev_Mon_R	1	200	11.14	11.14	0.0008	0.0010			Dropped	
Monthly_R	1	193	2.84	2.84	0.0922	0.0938			Dropped	

Table 3. Indices for total blacktip shark catch rates from 2004 to 2011 developed using the delta-lognormal model. The nominal frequency of occurrence, the number of samples (n), the Lo Index (numbers per 100 hook per hour), the Lo indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	*Frequency*	*n*	*Lo Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
2004	0.22727	44	0.60456	1.11550	0.47647	0.45143	2.75643
2005	0.58621	29	1.42387	2.62725	0.23578	1.64996	4.18341
2006	0.34286	35	0.40888	0.75445	0.54653	0.27138	2.09740
2007	0.38636	44	0.64497	1.19007	0.38897	0.56175	2.52117
2008	0.18182	33	0.39865	0.73557	0.54030	0.26732	2.02402
2009	0.12500	32	0.09947	0.18354	0.70970	0.05116	0.65838
2010	0.32203	59	0.62455	1.15239	0.34181	0.59275	2.24041
2011	0.10526	57	0.13073	0.24123	0.48718	0.09585	0.60710

Table 4. Summary of the backward selection procedure for building delta-lognormal submodels for the juvenile blacktip shark full index of relative abundance from 2004 to 2011.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 1875.5)*						*Lognormal Submodel Type 3 Tests (AIC 168.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	153	20.63	2.89	0.0044	0.0073	7	45	1.08	0.3903
Month	7	233	15.08	2.15	0.0349	0.0397	7	45	1.51	0.1898
location	1	264	0.15	0.15	0.6951	0.6955	1	45	0.68	0.4138
Depth	1	146	0.54	0.54	0.4636	0.4648	1	45	1.46	0.2325
Set	1	274	0.09	0.09	0.7586	0.7588	1	45	0.01	0.9289
Tempsur	1	220	4.25	4.25	0.0392	0.0404	1	45	0.26	0.6124
Tempbot	1	142	0.01	0.01	0.9170	0.9171	1	45	0.00	0.9590
Salsur	1	213	1.00	1.00	0.3181	0.3193	1	45	0.00	0.9700
Salbot	1	208	2.57	2.57	0.1087	0.1102	1	45	1.45	0.2354
DOsur	1	139	0.20	0.20	0.6543	0.6550	1	45	0.03	0.8676
DObot	1	162	0.79	0.79	0.3730	0.3743	1	45	2.09	0.1553
Prev_Mon_R	1	198	9.79	9.79	0.0018	0.0020	1	45	0.29	0.5954
Monthly_R	1	173	7.45	7.45	0.0063	0.0070	1	45	1.89	0.1760
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 1873.4)*						*Lognormal Submodel Type 3 Tests (AIC 163.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	154	21.12	2.96	0.0036	0.0062	7	46	1.13	0.3604
Month	7	234	15.78	2.25	0.0272	0.0314	7	46	1.54	0.1781
location	1	263	0.16	0.16	0.6849	0.6852	1	46	0.77	0.3841
Depth	1	145	0.53	0.53	0.4667	0.4678	1	46	1.53	0.2227
Set	1	275	0.11	0.11	0.7372	0.7375	1	46	0.01	0.9333
Tempsur	1	251	7.66	7.66	0.0056	0.0061	1	46	0.32	0.5732
Tempbot					Dropped		1	46	0.00	0.9512
Salsur	1	219	0.98	0.98	0.3229	0.3239			Dropped	
Salbot	1	217	3.08	3.08	0.0794	0.0808	1	46	1.89	0.1758
DOsur	1	133	0.18	0.18	0.6722	0.6729	1	46	0.03	0.8639
DObot	1	161	0.79	0.79	0.3754	0.3767	1	46	2.16	0.1483
Prev_Mon_R	1	198	9.85	9.85	0.0017	0.0020	1	46	0.31	0.5797
Monthly_R	1	175	7.46	7.46	0.0063	0.0070	1	46	2.06	0.1577

Model Run #3	*Binomial Submodel Type 3 Tests (AIC 1865.1)*						*Lognormal Submodel Type 3 Tests (AIC 159.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	148	25.36	3.54	0.0007	0.0015	7	47	1.17	0.3362
Month	7	233	16.49	2.35	0.0210	0.0246	7	47	1.59	0.1610
location	1	262	0.16	0.16	0.6894	0.6897	1	47	0.79	0.3790
Depth	1	142	0.58	0.58	0.4460	0.4472	1	47	1.56	0.2179
Set					Dropped		1	47	0.01	0.9144
Tempsur	1	256	7.86	7.86	0.0050	0.0054	1	47	0.48	0.4929
Tempbot					Dropped				Dropped	
Salsur	1	221	0.91	0.91	0.3413	0.3424			Dropped	
Salbot	1	218	3.26	3.26	0.0712	0.0726	1	47	1.99	0.1645
DOsur	1	141	0.12	0.12	0.7273	0.7278	1	47	0.03	0.8654
DObot	1	164	0.77	0.77	0.3798	0.3811	1	47	2.22	0.1431
Prev_Mon_R	1	188	9.89	9.89	0.0017	0.0019	1	47	0.33	0.5711
Monthly_R	1	166	7.81	7.81	0.0052	0.0058	1	47	2.11	0.1526

Model Run #4	*Binomial Submodel Type 3 Tests (AIC 1858.6)*						*Lognormal Submodel Type 3 Tests (AIC 155.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	148	25.36	3.54	0.0007	0.0015	7	147	27.12	3.79
Month	7	233	16.49	2.35	0.0210	0.0246	7	233	16.56	2.36
location	1	262	0.16	0.16	0.6894	0.6897	1	272	0.14	0.14
Depth	1	142	0.58	0.58	0.4460	0.4472	1	137	0.55	0.55
Set					Dropped				Dropped	
Tempsur	1	256	7.86	7.86	0.0050	0.0054	1	257	7.77	7.77
Tempbot					Dropped				Dropped	
Salsur	1	221	0.91	0.91	0.3413	0.3424	1	238	0.94	0.94
Salbot	1	218	3.26	3.26	0.0712	0.0726	1	220	3.24	3.24
DOsur	1	141	0.12	0.12	0.7273	0.7278			Dropped	
DObot	1	164	0.77	0.77	0.3798	0.3811	1	153	0.68	0.68
Prev_Mon_R	1	188	9.89	9.89	0.0017	0.0019	1	189	9.90	9.90
Monthly_R	1	166	7.81	7.81	0.0052	0.0058	1	169	7.73	7.73

Model Run #5	*Binomial Submodel Type 3 Tests (AIC 1860.1)*						*Lognormal Submodel Type 3 Tests (AIC 152.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	147	27.43	3.83	0.0003	0.0007	7	49	1.24	0.3015
Month	7	232	17.52	2.50	0.0143	0.0173	7	49	1.80	0.1094
location					Dropped		1	49	0.84	0.3635
Depth	1	145	0.85	0.85	0.3563	0.3578	1	49	1.61	0.2108
Set					Dropped				Dropped	
Tempsur	1	254	7.78	7.78	0.0053	0.0057	1	49	0.47	0.4960
Tempbot					Dropped				Dropped	
Salsur	1	230	0.84	0.84	0.3586	0.3596			Dropped	
Salbot	1	221	3.12	3.12	0.0774	0.0788	1	49	2.06	0.1580
DOsur					Dropped				Dropped	
DObot	1	153	0.65	0.65	0.4199	0.4212	1	49	2.35	0.1317
Prev_Mon_R	1	187	9.90	9.90	0.0017	0.0019	1	49	0.32	0.5726
Monthly_R	1	168	7.75	7.75	0.0054	0.0060	1	49	2.28	0.1374

Model Run #6	*Binomial Submodel Type 3 Tests (AIC 1862.5)*						*Lognormal Submodel Type 3 Tests (AIC 148.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	145	28.21	3.94	0.0002	0.0006	7	50	1.25	0.2949
Month	7	229	18.10	2.58	0.0115	0.0141	7	50	1.86	0.0960
location					Dropped		1	50	1.12	0.2957
Depth	1	141	0.73	0.73	0.3934	0.3948	1	50	1.63	0.2078
Set					Dropped				Dropped	
Tempsur	1	255	7.23	7.23	0.0072	0.0076	1	50	0.95	0.3334
Tempbot					Dropped				Dropped	
Salsur	1	232	0.94	0.94	0.3318	0.3328			Dropped	
Salbot	1	220	2.86	2.86	0.0906	0.0920	1	50	3.25	0.0773
DOsur					Dropped				Dropped	
DObot					Dropped		1	50	2.09	0.1548
Prev_Mon_R	1	179	9.55	9.55	0.0020	0.0023			Dropped	
Monthly_R	1	165	7.75	7.75	0.0054	0.0060	1	50	1.99	0.1649

Model Run #7	*Binomial Submodel Type 3 Tests (AIC 1851.3)*						*Lognormal Submodel Type 3 Tests (AIC 145.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	146	30.88	4.31	<.0001	0.0002	7	51	1.41	0.2223
Month	7	230	19.02	2.71	0.0081	0.0102	7	51	1.77	0.1142
location					Dropped		1	51	1.01	0.3206
Depth					Dropped		1	51	1.69	0.1991
Set					Dropped				Dropped	
Tempsur	1	260	7.51	7.51	0.0061	0.0066			Dropped	
Tempbot					Dropped				Dropped	
Salsur	1	236	0.69	0.69	0.4078	0.4087			Dropped	
Salbot	1	226	4.32	4.32	0.0376	0.0387	1	51	2.85	0.0973
DOsur					Dropped				Dropped	
DObot					Dropped		1	51	2.56	0.1161
Prev_Mon_R	1	178	9.68	9.68	0.0019	0.0022			Dropped	
Monthly_R	1	168	8.07	8.07	0.0045	0.0051	1	51	1.75	0.1919

Model Run #8	*Binomial Submodel Type 3 Tests (AIC 1841.9)*						*Lognormal Submodel Type 3 Tests (AIC 144.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	142	30.61	4.27	<.0001	0.0003	7	52	1.45	0.2060
Month	7	226	19.43	2.77	0.0069	0.0089	7	52	1.82	0.1023
location					Dropped				Dropped	
Depth					Dropped		1	52	1.23	0.2717
Set					Dropped				Dropped	
Tempsur	1	254	6.71	6.71	0.0096	0.0102			Dropped	
Tempbot					Dropped				Dropped	
Salsur					Dropped				Dropped	
Salbot	1	238	12.39	12.39	0.0004	0.0005	1	52	2.01	0.1622
DOsur					Dropped				Dropped	
DObot					Dropped		1	52	2.98	0.0905
Prev_Mon_R	1	164	9.15	9.15	0.0025	0.0029			Dropped	
Monthly_R	1	170	7.85	7.85	0.0051	0.0057	1	52	1.63	0.2075

Model Run #9	*Binomial Submodel Type 3 Tests (AIC 1841.9)*						*Lognormal Submodel Type 3 Tests (AIC 142.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	142	30.61	4.27	<.0001	0.0003	7	53	1.65	0.1414
Month	7	226	19.43	2.77	0.0069	0.0089	7	53	1.88	0.0919
location					Dropped				Dropped	
Depth					Dropped				Dropped	
Set					Dropped				Dropped	
Tempsur	1	254	6.71	6.71	0.0096	0.0102			Dropped	
Tempbot					Dropped				Dropped	
Salsur					Dropped				Dropped	
Salbot	1	238	12.39	12.39	0.0004	0.0005	1	53	1.51	0.2243
DOsur					Dropped				Dropped	
DObot					Dropped		1	53	2.35	0.1309
Prev_Mon_R	1	164	9.15	9.15	0.0025	0.0029			Dropped	
Monthly_R	1	170	7.85	7.85	0.0051	0.0057	1	53	1.40	0.2421

Model Run #10	*Binomial Submodel Type 3 Tests (AIC 1841.9)*						*Lognormal Submodel Type 3 Tests (AIC 138.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	142	30.61	4.27	<.0001	0.0003	7	54	1.69	0.1316
Month	7	226	19.43	2.77	0.0069	0.0089	7	54	1.85	0.0968
location					Dropped				Dropped	
Depth					Dropped				Dropped	
Set					Dropped				Dropped	
Tempsur	1	254	6.71	6.71	0.0096	0.0102			Dropped	
Tempbot					Dropped				Dropped	
Salsur					Dropped				Dropped	
Salbot	1	238	12.39	12.39	0.0004	0.0005	1	54	1.08	0.3032
DOsur					Dropped				Dropped	
DObot					Dropped		1	54	2.91	0.0936
Prev_Mon_R	1	164	9.15	9.15	0.0025	0.0029			Dropped	
Monthly_R	1	170	7.85	7.85	0.0051	0.0057			Dropped	

Model Run #11	*Binomial Submodel Type 3 Tests (AIC 1841.9)*						*Lognormal Submodel Type 3 Tests (AIC 134.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	142	30.61	4.27	<.0001	0.0003	7	55	1.86	0.0933
Month	7	226	19.43	2.77	0.0069	0.0089	7	55	2.12	0.0564
location					Dropped				Dropped	
Depth					Dropped				Dropped	
Set					Dropped				Dropped	
Tempsur	1	254	6.71	6.71	0.0096	0.0102			Dropped	
Tempbot					Dropped				Dropped	
Salsur					Dropped				Dropped	
Salbot	1	238	12.39	12.39	0.0004	0.0005			Dropped	
DOsur					Dropped				Dropped	
DObot					Dropped		1	55	4.53	0.0378
Prev_Mon_R	1	164	9.15	9.15	0.0025	0.0029			Dropped	
Monthly_R	1	170	7.85	7.85	0.0051	0.0057			Dropped	

Table 5. Indices of juvenile blacktip shark catch rates from 2004-2011 developed using the delta-lognormal model. The nominal frequency of occurrence, the number of samples (n), the Lo Index (number per 100 hook per hour), the Lo indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	n	Lo Index	Scaled Index	CV	LCL	UCL
2004	0.22727	44	0.70478	1.74518	0.49211	0.68762	4.42924
2005	0.44828	29	1.10147	2.72745	0.36052	1.35559	5.48763
2006	0.25714	35	0.26374	0.65307	0.66374	0.19507	2.18646
2007	0.29545	44	0.35902	0.88901	0.56315	0.31119	2.53968
2008	0.12121	33	0.13303	0.32940	0.97446	0.06427	1.68818
2009	0.06250	32	0.02587	0.06406	2.55025	0.00375	1.09576
2010	0.27119	59	0.58344	1.44471	0.59282	0.48207	4.32965
2011	0.07018	57	0.05941	0.14712	1.17127	0.02293	0.94380

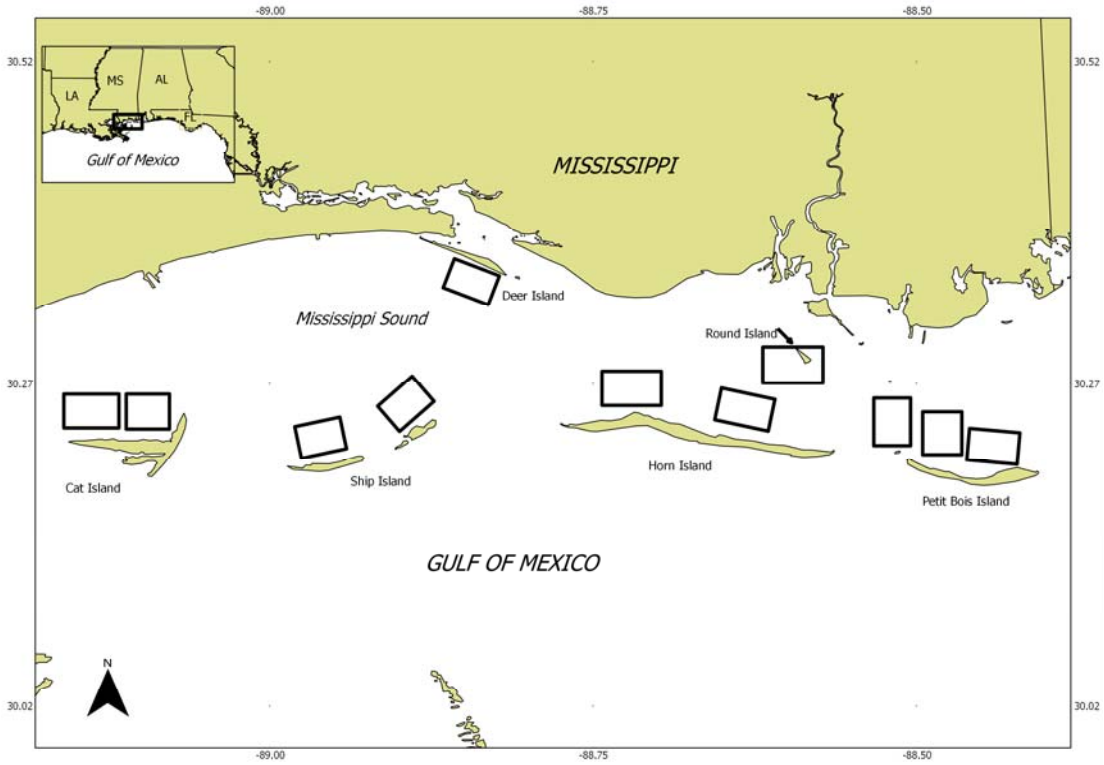


Figure 1. Sampling universe for the Mississippi bottom longline survey. Each rectangle (~10.6 km^2) represents a sampling region where sampling locations were randomly selected.

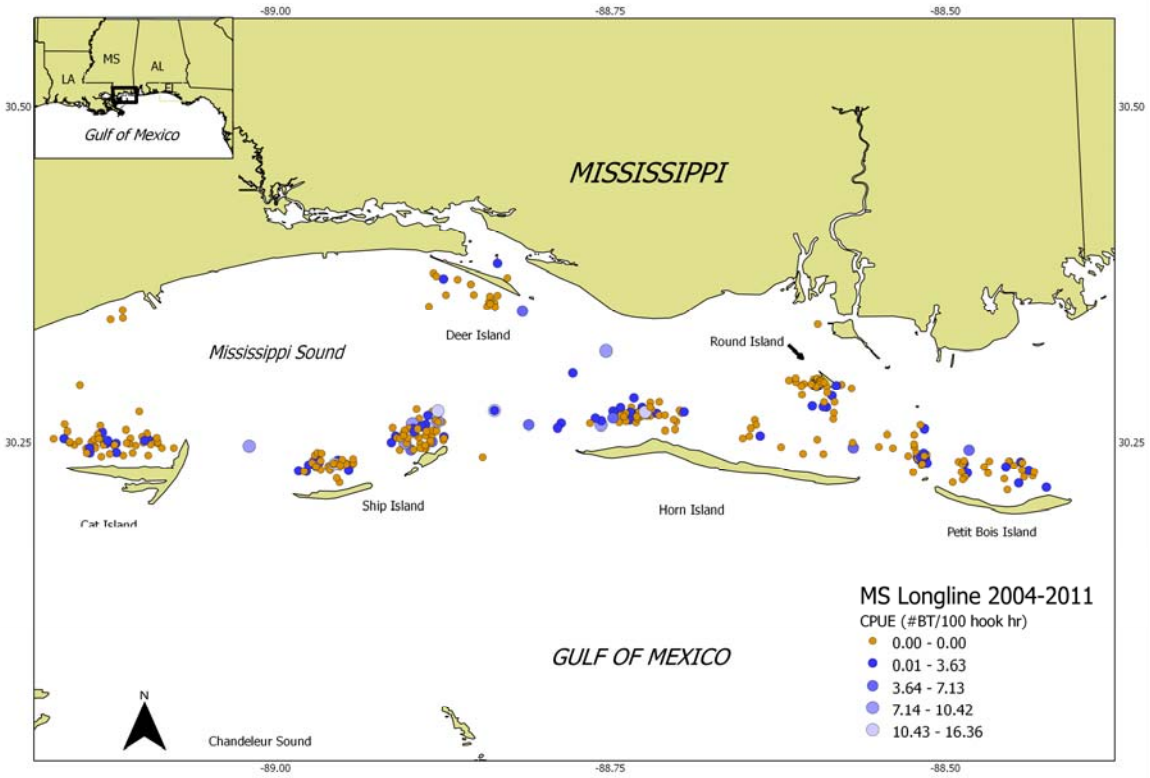


Figure 2. Stations sampled from 2004 to 2011 during the Mississippi bottom longline survey with total blacktip shark CPUE presented.

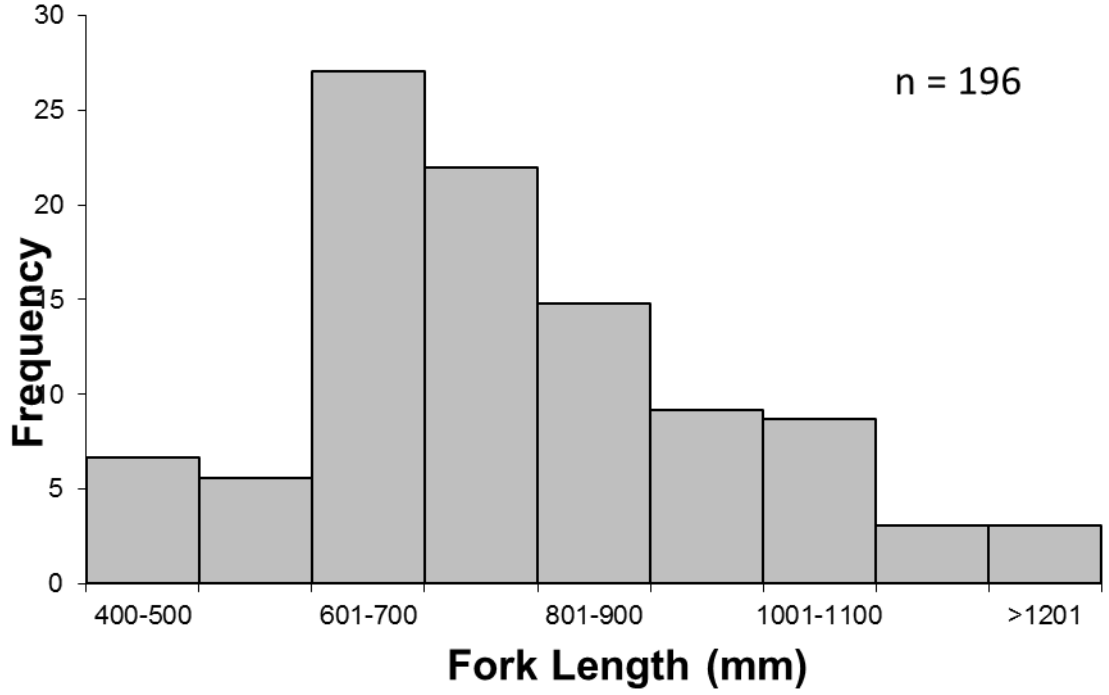


Figure 3. Length frequency distribution for blacktip sharks caught during the Mississippi bottom longline survey from 2004-2011.

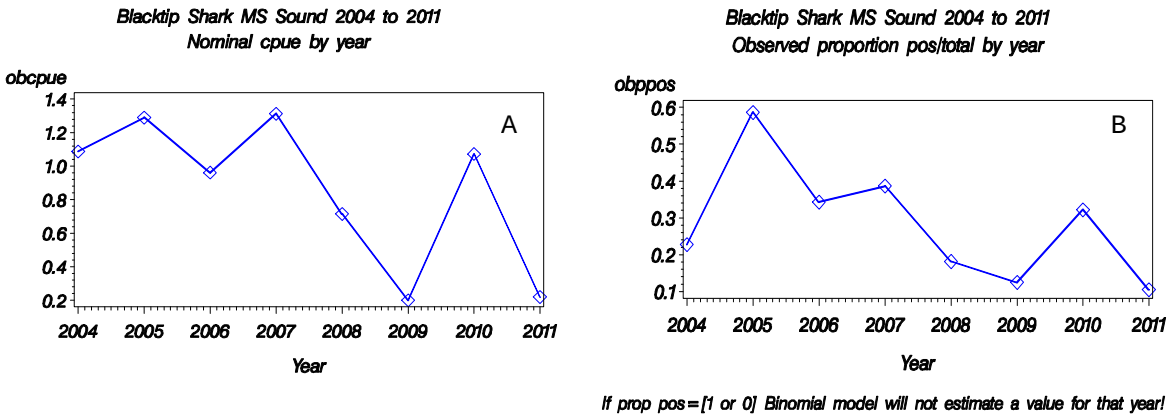


Figure 4. Annual trends for total blacktip sharks captured during Mississippi bottom longline surveys from 2004 to 2011 in **A.** nominal CPUE and **B.** proportion of positive stations.

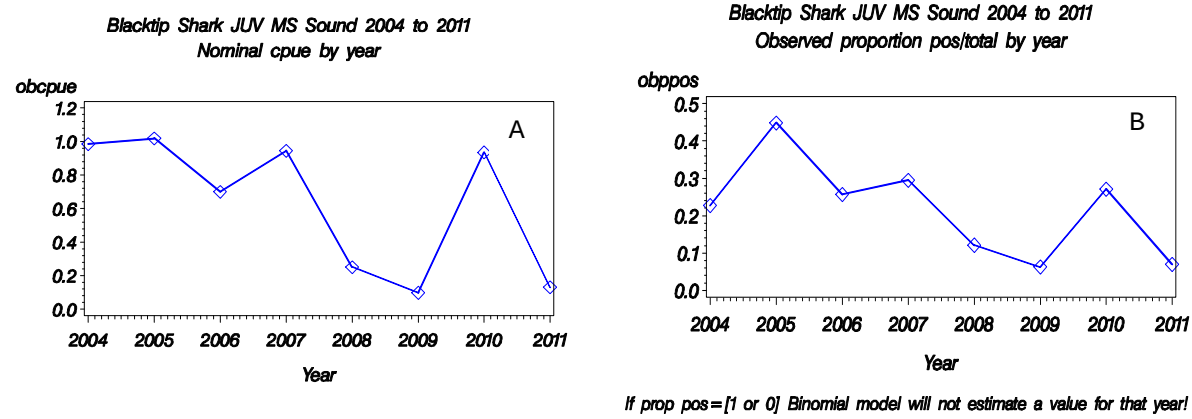


Figure 5. Annual trends for Juvenile blacktip sharks captured during Mississippi bottom longline surveys from 2004 to 2011 in **A.** nominal CPUE and **B.** proportion of positive stations.

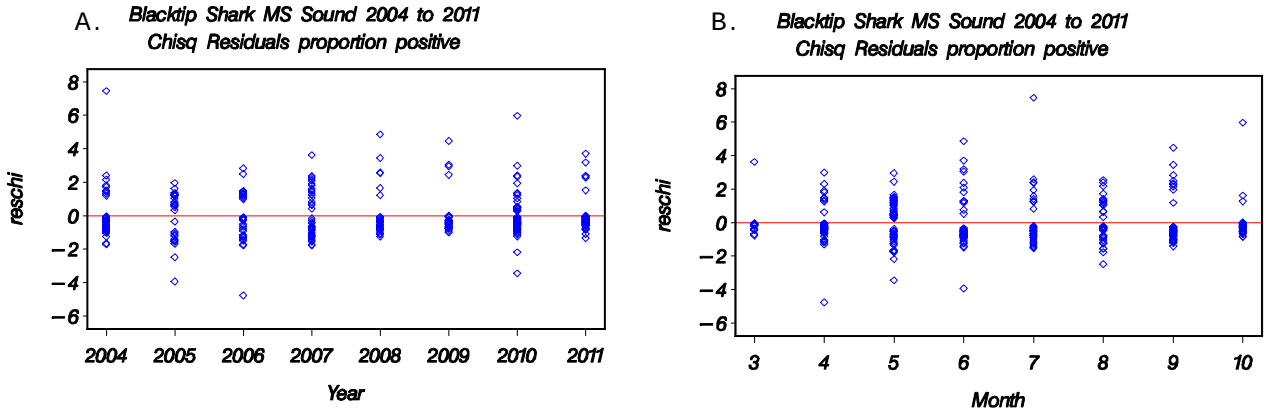


Figure 6. Diagnostic plots for the binomial component of the total blacktip shark Mississippi bottom longline survey model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by month.

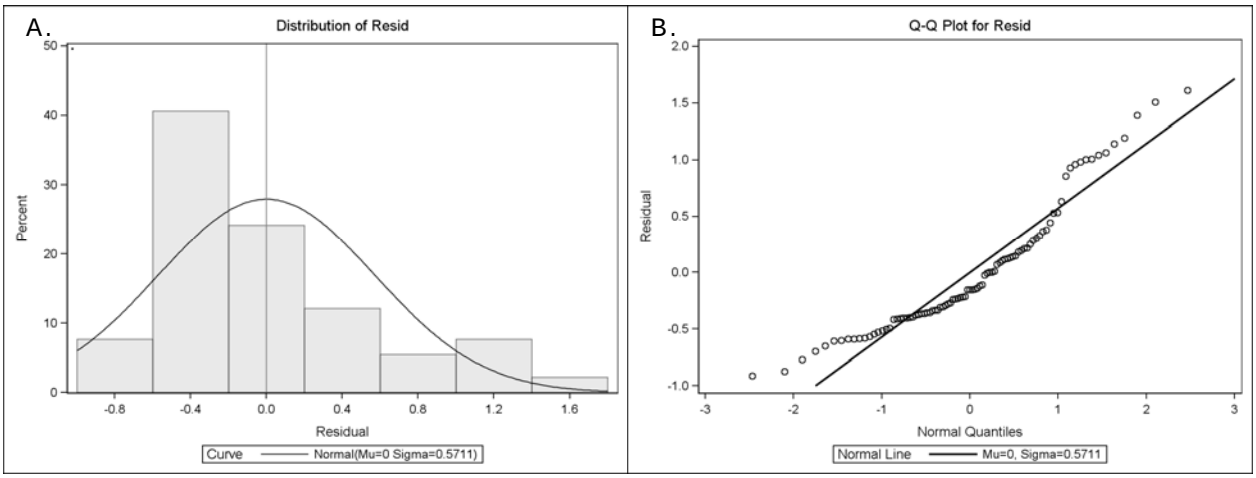


Figure 7. Diagnostic plots for the lognormal component of the total blacktip shark Mississippi bottom longline survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

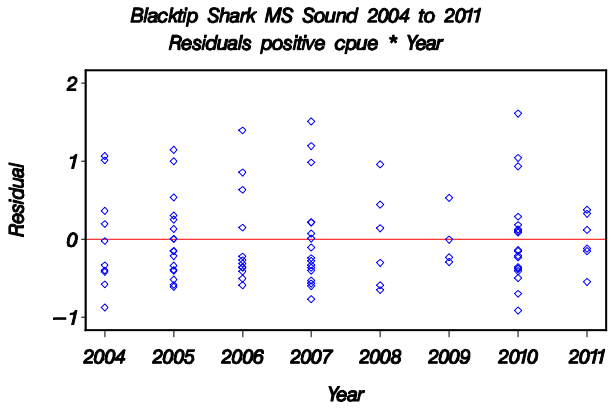


Figure 8. Diagnostic plot of the Chi-Square residuals by year for the lognormal component of the total blacktip shark Mississippi bottom longline survey model.

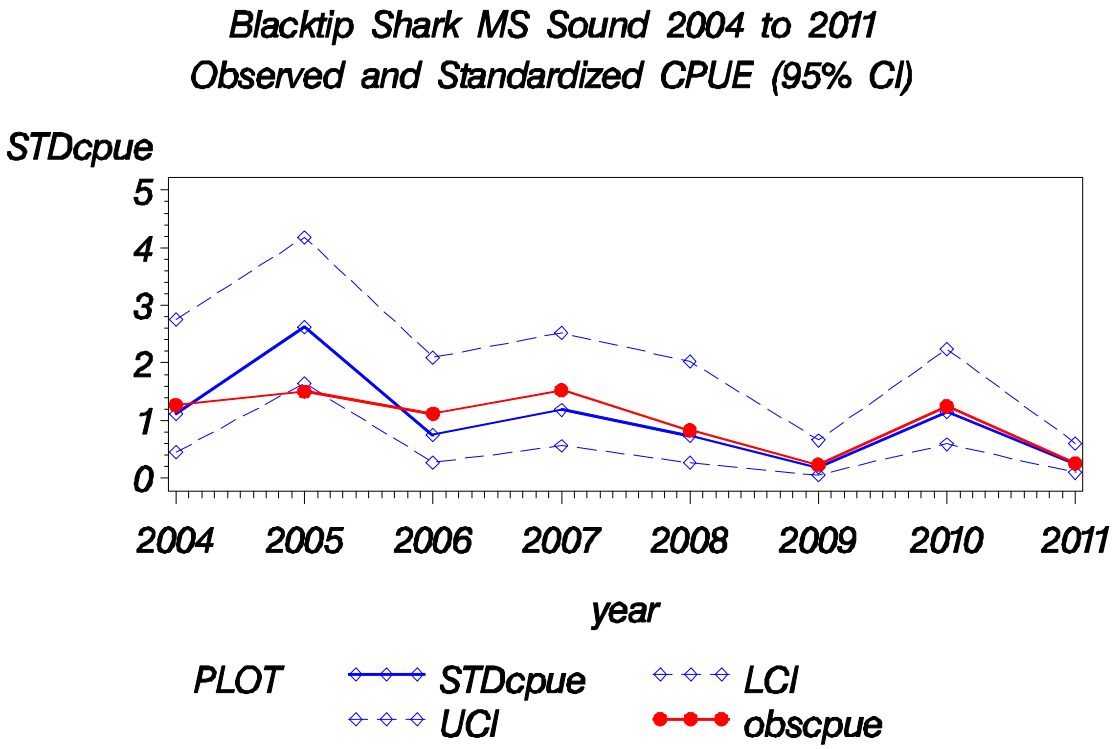


Figure 9. Observed and standardized CPUE for total blacktip shark catch in the Mississippi bottom longline survey from 1998-2011.

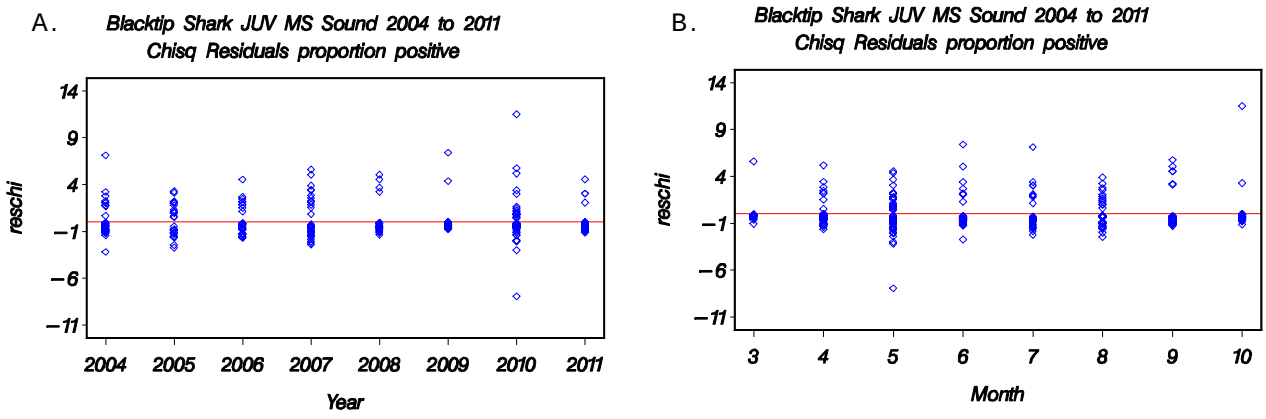


Figure 10. Diagnostic plots for the binomial component of the juvenile blacktip shark Mississippi bottom longline survey model: **A.** the Chi-Square residuals by year, and **B.** the Chi-Square residuals by month.

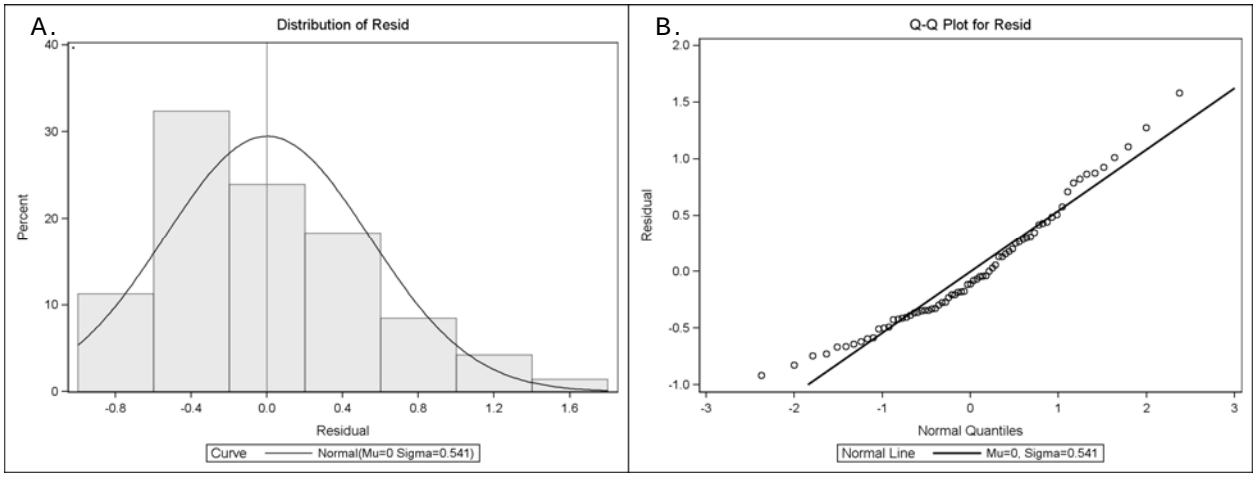


Figure 11. Diagnostic plots for the lognormal component of the juvenile blacktip shark Mississippi bottom longline survey model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

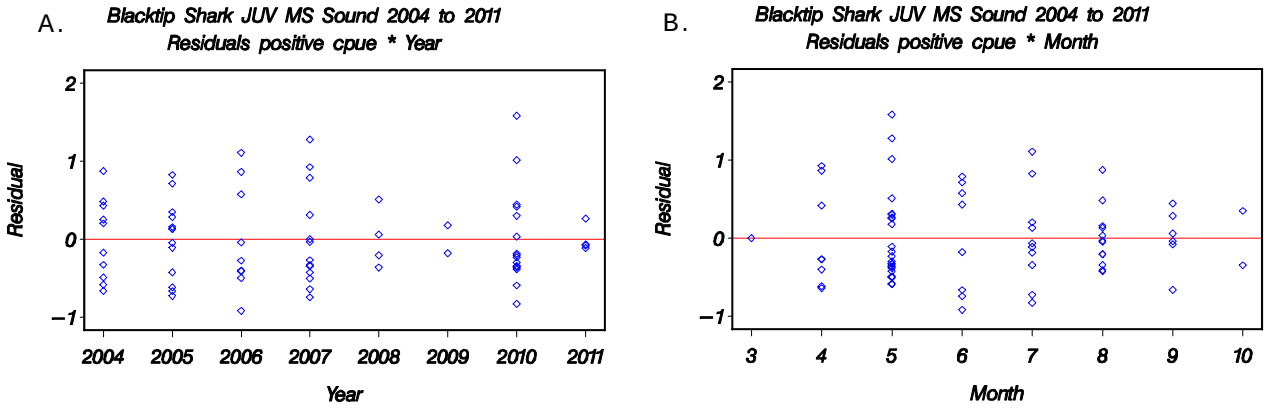


Figure12. Diagnostic plots for the lognormal component of the juvenile blacktip shark Mississippi bottom longline survey model: **A.** the Chi-Square residuals by year, and **B.** the Chi-Square residuals by month.

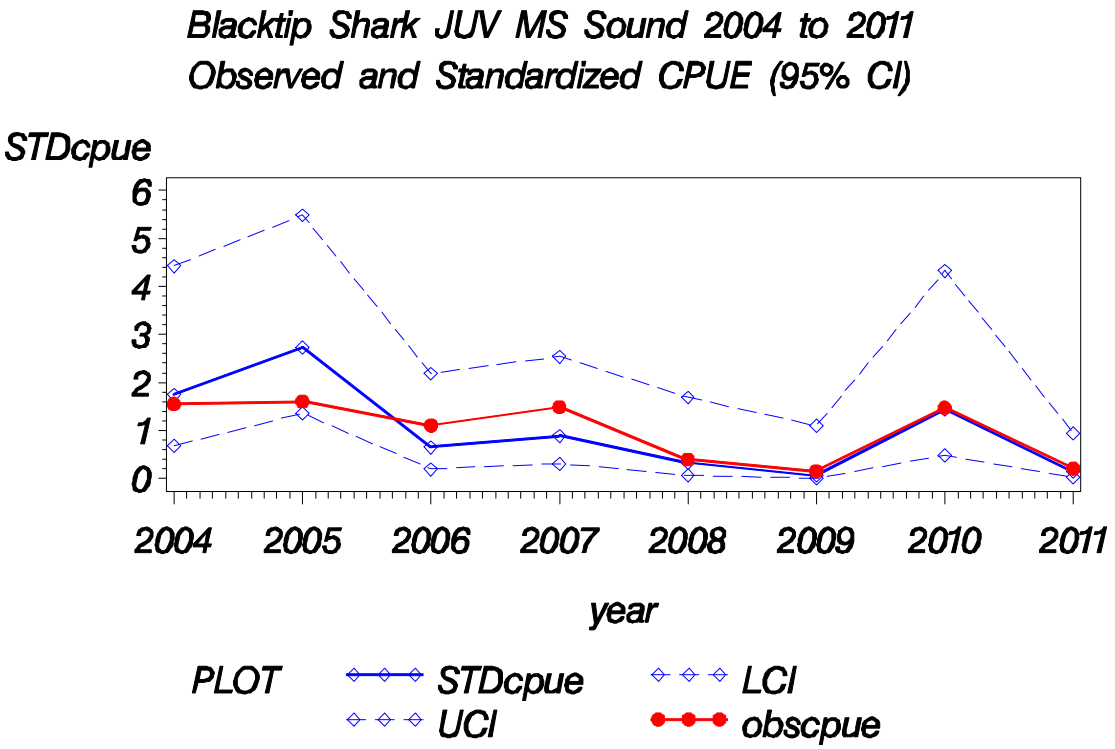
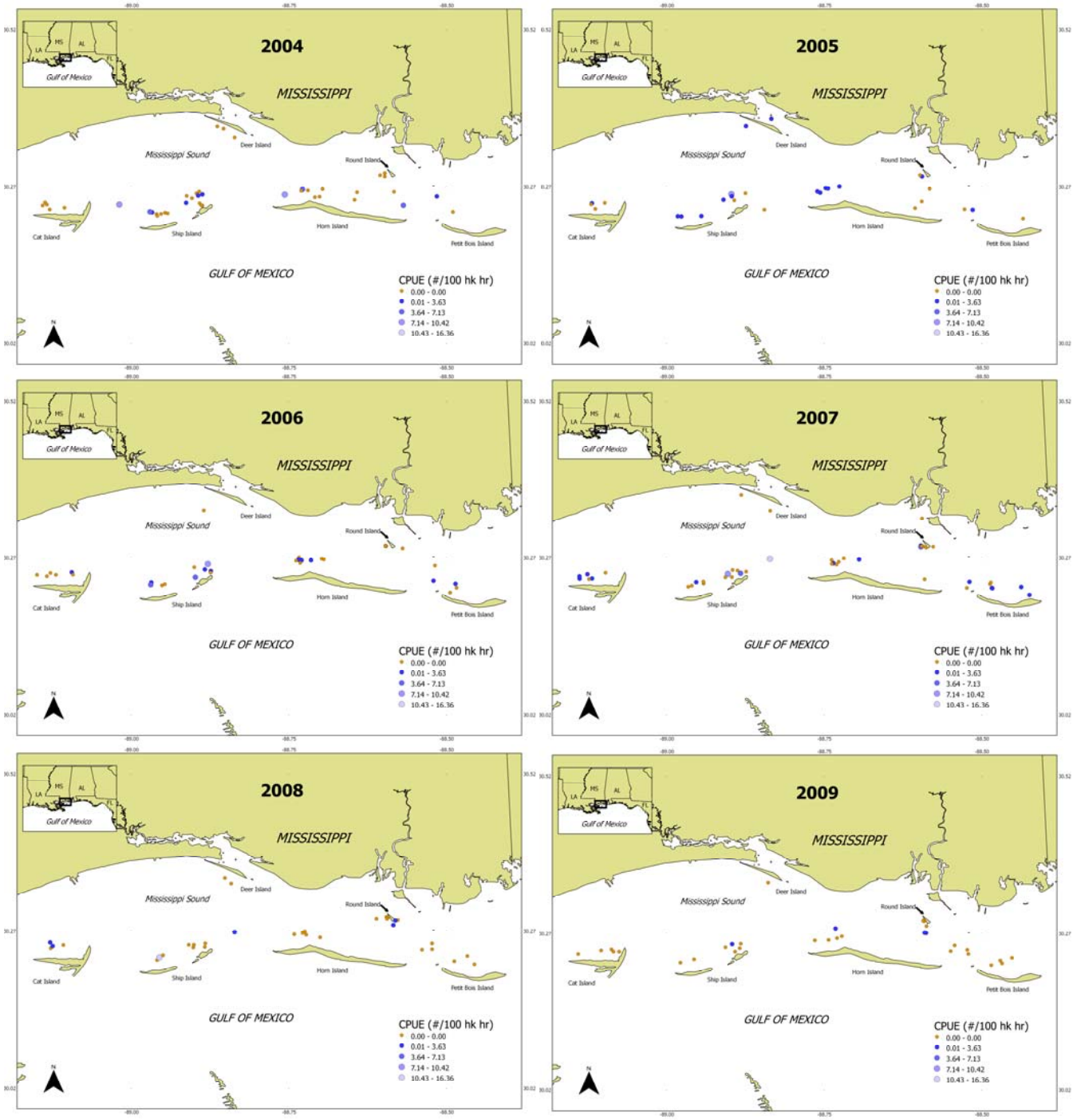


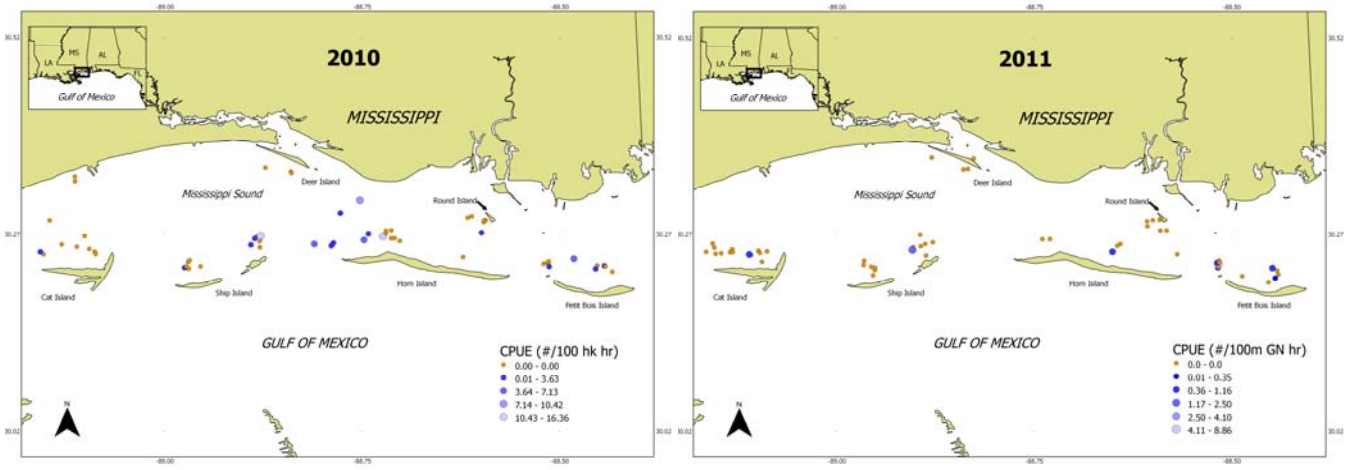
Figure 13. Observed and standardized CPUE for juvenile blacktip shark catch in the Mississippi bottom longline survey from 2004-2011.

Appendix:

Annual Effort and Catch

Appendix Figure 1. Annual survey effort and catch of blacktip sharks from the Mississippi bottom longline survey from 2004-2011.




2010
MISSISSIPPI
Gulf of Mexico
Mississippi Sound
Deer Island
Round Island
Cat Island
Ship Island
Horn Island
Petit Bois Island
GULF OF MEXICO
CPUE (#/100 hk hr)
0.00 - 0.00
0.01 - 3.63
3.64 - 7.13
7.14 - 10.42
10.43 - 16.36
2011
MISSISSIPPI
Gulf of Mexico
Mississippi Sound
Deer Island
Round Island
Cat Island
Ship Island
Horn Island
Petit Bois Island
GULF OF MEXICO
CPUE (#/100m GN hr)
0.0 - 0.0
0.01 - 0.35
0.36 - 1.16
1.17 - 2.50
2.50 - 4.10
4.11 - 8.86